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THE COSCINODISCEÆ.—NOTES ON SOME UNRELIABLE CRITERIA OF GENERA AND SPECIES.

JACOB D. COX, A. M., LL. D.

Description of Plates 4 and 5.

Fig. 1.—*Coscinodiscus subtilis,* Ehr., craticular form. Fossil. × 1050. Petersburg, Va.

" 2.—*Cos. oculus-iridis,* Ehr., outer surface of rosette. Fossil. × 1300. Nottingham, Md.

" 3.—*Cos. oculus-iridis,* Ehr., inner surface of rosette. Fossil. × 1300. Nottingham, Md.

" 4.—*Cos. excentricus,* Ehr. Fossil. × 750. Nankoori Island.

" 5.—*Cos. radiatus,* Ehr., triangular form. Fossil. × 400. Beach Haven, N. J.

" 6.—*Actinocyclus Ralfsii,* var. *Monicæ,* Grun. Fossil. × 800. Sta. Monica, Cal.

" 7.—*Cos. radiolatus,* Ehr. (*C. curvatulus,* Grun.). Fossil. × 1000. Moron, Spain.

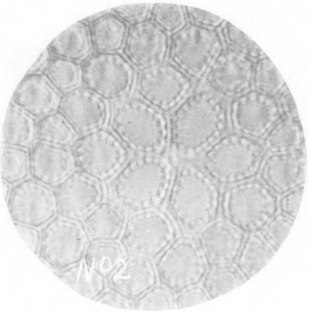
" 8.—*Cos. radiolatus,* Ehr., craticular plate. Fossil. × 600. Barbadoes.

" 9.—*Actinocyclus interpunctatus,* Brightwell, var. Fossil. × 1000. San Luis Obispo, Cal.

" 10.—*Actinocyclus interpunctatus,* Brightwell, var. Fossil. × 800. Sta. Monica, Cal.

If I needed a text for what I have to say it would be hard to find a more appropriate one than the following extract from the last annual address of Dr. C. T. Hudson, President of the Royal Microscopical Society of London.

"The multiplication of species," he says, "is a crying evil, and the exasperating alterations of their names in consequence of changing classifications is another. The former, of course, is mainly due to the difficulty (no doubt a very great one) of determining what shall be a species and what a variety." In illustration of this he refers to the fact, mentioned by Darwin, that "one expert has made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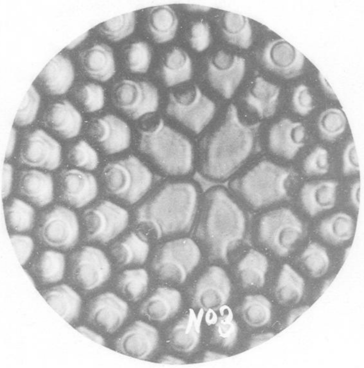
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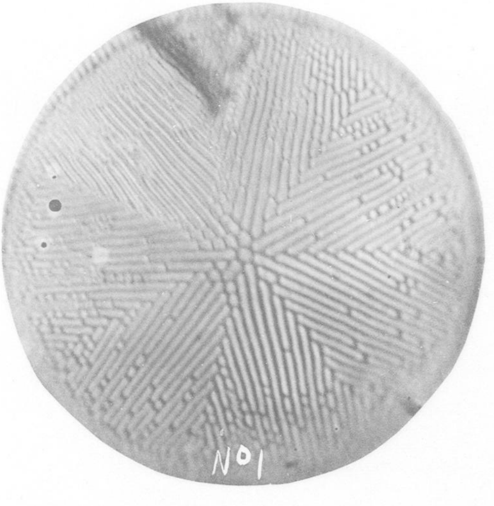
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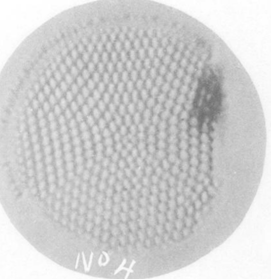
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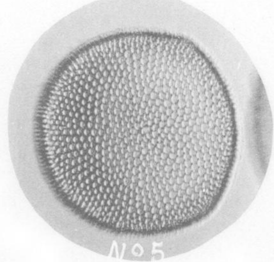
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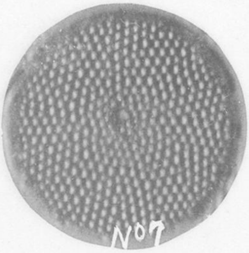

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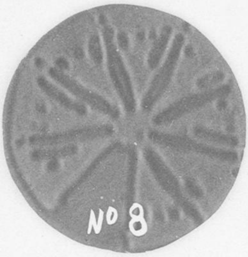

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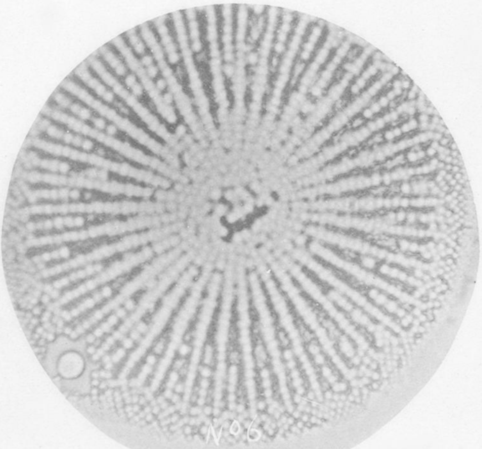

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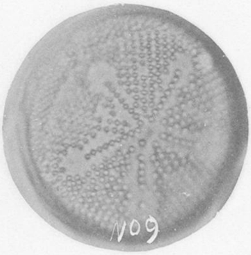

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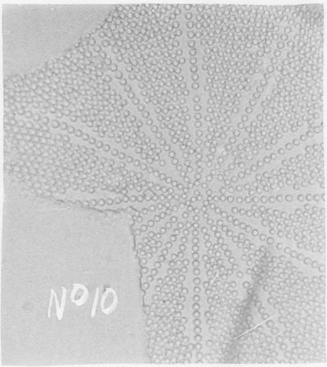

No 10

no fewer than thirty-seven species of one set of forms which another arranges in three." *

As long ago as 1863 Dr. Greville, in his monograph on the genus Auliscus, recognized the danger of his own large additions to the *Diatomaceæ*, but spoke of his work as an accumulation of materials which could " only be accomplished at the risk of encumbering both genera and species, more or less, with a provisional nomenclature." That he really regarded his new lists as more or less provisional was shown by his quoting from Professor Walker-Arnott (another distinguished worker in the same field) the statement that " the time may ere long arrive when what are now called genera or sub-genera will alone be considered species, and another Linnæus be requisite to reduce the chaos to order." †

If the multiplication of species of diatoms seemed portentous in 1863 what shall we say of it now, when the Habirshaw-Chase catalogue contains about ten thousand, and the additions have never been so rapid as since that catalogue was prepared? It is true to-day, as it was thirty years ago, that the students of microscopical botany who have been most familiar with the life history of the diatoms have generally been the most conservative in the admission of new species. Such investigators as Van Heurck on the continent of Europe, Kitton in England, Gregory in Scotland, and H. L. Smith in this country are examples of strong opposition to the rush for new names. Professor Smith's Conspectus was a bold reduction of the overcrowded list of genera, and has been generally accepted as a work of needed reform, though at first it seemed to many too radical in its retrenchments.

I do not propose to discuss the question, what is a species? I wish to deal with a more practical matter by calling attention to some things which seem to me to have been unsoundly assumed to be criteria of specific distinction. If I am right, the foundation will be laid for a considerable diminution of the list of species of *Coscinodiscus* at least, and, as I think, will help in the application of a similar criticism to other genera. I shall only assume it to be a maxim of the law of classification that a new distinction of species shall not be based upon trivial, uncertain, or fleeting characters in the specimen under examination, and that those species, so called, which cannot stand this test shall be cancelled.

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* Journal R. M. S., February, 1890, p. 134.

† Transactions R. M. S., 1863, pp. 39-41.

What I wish to say will arrange itself most readily about seven typical forms, as follows:

1. *Actinocyclus ehrenbergii, Ralfs.*
2. *Coscinodiscus subtilis, Ehr.*
3. *Cos. radiolatus, Ehr.*
4. *Cos. lineatus, Ehr.*
5. *Cos. radiatus, Ehr.*
6. *Cos. centralis, Ehr.*
7. *Cos. Marginatus, Ehr.*

Leaving out of view some irregular and doubtful forms, these seven may be taken as types of the natural divisions into which the genus *Coscinodiscus* separates, the distinguishing marks of these species being the most obvious, persistent, and trustworthy criteria for a subdivision of the genus. I shall defer, for a little, the statement of my reasons for including *Actinocyclus ehrenbergii.* They will appear as the discussion proceeds.

In all these we find those marks of the genus which may be considered as the generic pattern or norm, viz., a disc, circular, of shallow arch (nearly flat); the disc surface covered with alveoli of uniform character (round or hexagonal), the hoop (connecting zone) smooth and narrow as compared with the diameter of the disc. It is not necessary for my present purpose to consider the negative marks of distinction from other genera. All of these marks may be subject to exceptions and variations, for we are dealing with living things, not geometrical figures, and a living thing is never strictly geometric in figure, however it may approximate to this. In scientific classification, the exception may fairly prove the rule when the rule is based on sound induction. It does not destroy the faith of a naturalist in his classification, for instance, if he finds triangular forms classed both with those regarded as normally circular and those normally oval or lozenge-shaped, provided the different triangular forms have characteristics which indicate their closer relation to the circular norm on the one hand, or to the oval on the other.

Passing, then, from the generic marks of the seven species I have named, we find that they differ from each other by definite and easily distinguishable characters.

1. *Actinocyclus ehrenbergii, Ralfs.*

The disc is divided into compartments or segments by radial lines of alveoli, at the marginal end of each of which is a small spine.

Each compartment is filled by a fascicle of lines of alveoli of which the middle line is radial and the other lines parallel to the middle one. The outer rim is beveled or curved sharply beyond the spines, and upon this are more numerous lines of finer alveoli, making decussating as well as radial striæ. A "pseudo-nodule" is near the margin.

2. *Coscinodiscus subtilis, Ehr.*

Marking of the disc like the last, except that the radial lines between the fascicles are omitted and the parallel lines of the wedge-shaped fascicles are lengthened till those of adjacent fascicles touch. The small spine is at the marginal end of the middle line of the fascicle. Beveled rim beyond the spines similar to last. No pseudo-nodule.

3. *Coscinodiscus radiolatus, Ehr.*

Marking of the disc similar to the last, except that the fascicles are each formed by a radial line with parallel lines on one side of it only, the fascicles being all similar to each other and symmetrical. The small spine is at the end of the radial line forming the side of the fascicle.

4. *Coscinodiscus lineatus, Ehr.*

The disc covered with alveoli in straight lines parallel to a diameter and arranged in *quincunx*, so that when the round alveolus becomes hexagonal the surface of the disc resembles a true honeycomb, the most prominent lines in appearance being parallel to the given diameter; a loose circle of small spines marginal or intra-marginal.

5. *Coscinodiscus radiatus, Ehr.*

Marking of the disc made up of hexagonal alveoli in radial lines, which, starting from a central rosette, bifurcate as they go outward, so that there are rarely continuous straight radial lines of alveoli. In robust specimens the upper surface of each alveolus has a dotted appearance, caused by finer secondary pits or marks.

6. *Coscinodiscus centralis, Ehr.*

Marking of the disc of hexagonal, round or sub-quadrate alveoli, which, starting near the center, go outward in continuous radial lines, new radial lines being intercalated as room is made by the outward divergence. Secondary marking in robust specimens: In large examples the central zone is thin, and the outer zone relatively robust and thick.

7. *Coscinodiscus marginatus, Ehr.*

Marking of the disc sub-hexagonal alveoli, without traceable scheme of radiation, but in largest specimens approaching *Cos. radiatus.* Margin strongly recurved and produced, so as to make a more and more deeply cup-shaped valve in each new frustule formed by fission, the small valves being thus most deeply cupped in a given brood and the large valves most flat.

The last of this list has the most disputable claim to specific distinction, but the balance of reasons seems to incline in favor of recognizing it.

My inclusion of *Actinocyclus* in the genus *Coscinodiscus* is based upon the fact that it is so plainly one of the series of fasciculate forms that we must either make a genus of each of them or include all under one. In considering what I regard as insufficient generic criteria I will begin with this :

A. The so-called pseudo-nodule of *Actinocyclus* is less important as a generic mark than the other characteristics which are identical with the fasciculate *Coscinodisci.*

In classification we certainly ought to proceed from more widely distributed marks to those less so. In all the more noticeable characters, *Actinocyclus* agrees with *Coscinodiscus subtilis.* The difference is analogous to that which was once supposed to be a good specific distinction, viz., the number of fascicles. The fasciculate character is common to all. The number of fascicles differs. If this difference were persistent, it might be a good basis for establishing a variety, but it is so plainly a subdividing of the fasciculate class that it cannot be regarded as other than a distinction of inferior grade. For this reason the pseudo-nodule with the radial lines of alveoli separating the fascicles may be taken together as making a good distinction of species but not of genus.

The earlier idea was that the pseudo-nodule had some important distinctive physiological character. No evidence of this has been found, and it is now commonly regarded as a mere shell marking, not a process. It is less important as a distinction than the processes of *Cos. concinnus,* and hardly more so than the central smooth space of *Cos. perforatus,* once supposed to be an opening in the shell.

The occasional appearance of the pseudo-nodule in other *Coscinodisci,* as in *Actinocyclus curvatulus, Janisch,* is evidence of relationship between species (as far as it goes); but I agree with Schmidt in regarding the last-named form as having the more numerous and strong marks of *Cos. curvatulus, Grunow*, the presence of the pseudonodule being the exceptional fact in the diagnosis. (See Schmidt's Atlas, pl. lvii, fig. 31.)

B. Color is an untrustworthy mark of species.

Color in diatoms of all genera is among the most variable and illusive of marks. It depends upon the lamination, which produces iridescence in these forms as in mother-of-pearl; but lamination proceeds by additional deposition of the silex through the whole growth of the diatom. In its earliest life, when the silicification is imperfect and the fibrous vegetable character of the tissue preponderates, there is no iridescence, even in *Actinocyclus*. Vigorous, strongly silicified specimens shine with brilliant prismatic colors; but we find decay, due to chemical action, often setting in after death, and extensive fossil deposits will give us innumerable *Actinocycli* as pale and void of color as cotton cloth. Again, the color depends on the magnifying power used in examining the shell. One which is brilliant under a "two-thirds" objective will be colorless under an "eighth." Still again, the tint and character of the rings will be varied by a slight tilt or inclination of the plane of the shell as well as by the robustness of the lamination and the slightest variation in regular curve of the surface. Old and partially corroded diatoms are often found with the laminæ partly removed. *Actinocyclus* is very liable to this, the thickened patches being often almost black, giving rise to false species and varieties.

C. The number of fascicles is no mark of species.

This seemed so obvious and clear a natural distinction that it was inevitable that early observers should base new species upon it. Ehrenberg ransacked astronomy and mythology for new names to the five or six score species of *Actinocyclus* thus made, but naturalists gave a sigh of relief when Ralfs swept them away. We do not know more than that this is a most variable character. We sometimes find very few fascicles and sometimes very many in shells having such relation to each other as to tempt us to make the difference more significant than it is. Investigation has, however, detected a difference in the number of fascicles in the two valves of a single frustule, and the accepted generalization of Ralfs has thus been justified. Yet there has been a curious persistence in treating the distinction as worth something in an extreme case. If we take the scheme of the formation of *Actinocyclus* fascicles and consider the effect of increasing the number and correspondingly diminishing the lines in each fascicle it is evident that we come at last (or in the next to the last step) to a fascicle of three lines, the middle one a radius and the other two very short and near the margin. At first blush we seem to have only an arrangement of alternately long and short lines; but if the radial lines *between* the fascicles are taken into the account we shall see that the form which I have photographed in plate 5, fig. 6, is the regular form of *Actinocyclus* with the fascicles thus reduced to a minimum size. To it a number of different names have been given, and it appears in Van Heurck's atlas as *Actinocyclus ralfsii, var. Monicæ Grunow* (Van H., pl. cxxiv, fig. 3). *Coscinodiscus biradiatus, Greville,* and *Coscinodiscus scintillans, Greville,* are either the same or varieties of the same. In the last named, as exhibited in H. L. Smith's "Species Typicæ," No. 99, I have found the pseudo-nodule unmistakably present in instances enough to decide the question, though the surface of these shells is so irregular, owing to the scaling off of laminæ, that the inconspicuous pseudo-nodule may easily be overlooked. My note book for 1884 shows that I reached this conclusion after an examination then made.

My observation leads me to suggest the following as the lines of *tendency* in variation among the fasciculated forms: *Actinocyclus* varies more in the number of fascicles and the reduction of the number of lines in the fascicle; *Cos. subtilis* varies more in the regularity of the fascicle. This, of course, is offered as only true in a general way.

D. The so-called subulate spaces in *Actinocyclus* are not marks of distinction of species.

These spaces are those which occur at the inner end of each line of a fascicle, bounded on one side by the next longer line of the fascicle and on the other by the radial line between the fascicles. It is clearly illustrated by plate 5, fig. 10, which is from a very symmetric specimen in the Santa Monica, Cal., deposit. If the marking of the specimen is loose, the spaces will be relatively large; if compact, they will be relatively small; if stoutly silicated, they will sometimes look almost or quite black and be very prominent. The marking is often so compact that the radial lines between fascicles are wavy, as if they were pressed into these spaces, almost obliterating them. Variations in these respects may be found in the examples of any pure gathering of any one of the supposed numerous species of *Actinocyclus*. An observer happens to find a specimen more than usually noticeable in the one or other extreme and names it as a new species. It seems to me utterly unreliable as a specific distinction. The curious fate of Brightwell's *Actinocyclus interpunctatus* is worth noticing. He described sufficiently well, according to the distinctions of genera then received, an *Actinocyclus* with unusually prominent double lines of subulate spaces. His reference to the confusion between *Actinocyclus*, *Actinoptychus*, and *Eupodiscus*, then common, and especially what he says of Ehrenberg's use of the number of fascicles, as a specific distinction, leaves no room for dispute that he had a true *Actinocyclus* under his eye. He says* "The true species of this and the preceding genus we believe to be few, while Ehrenberg, falling into the extraordinary error of viewing every variation in the number of rays or septa as a species, has made a fresh nomenclature and a new description of nearly all the species necessary." It was this suggestion, no doubt, which Ralfs, in the following year, carried out in the new edition of Pritchard's Infusoria (1861), by condensing the hundred or more species into *Actinocyclus ehrenbergii*. Even Brightwell's figure was fairly good as figures then went, before photographic methods, and his references to habitat (in Monterey earth, amongst other places) help identify his specimen; yet Grunow identified it as his *Hyalodiscus stelliger* of the Moller type plate. H. L. Smith showed this last to be no *Hyalodiscus* at all, but a *Coscinodiscus* (*C. interpunctatus, H. L. S.*†). Prof. Smith's conclusion as to *H. stelliger* has been generally received; but instead of following him in correcting the error by reinstating Brightwell's *A. interpunctatus*, this has been dropped by latest systematists, and the form has been named half a dozen times over as a new discovery. In the series of photographs which I deposit with the custodian of the Society as supplementary to the plates published, No. 1, of *Actinocyclus ehrenbergii* from a recent gathering from the Oregon coast, Pacific Ocean, very fairly shows what Brightwell intended to describe as "double rays running from the center to near the circumference, the rays composed of short broken lines." With this compare Nos. 2, 3, 4 of same series.‡

The changes in diatom marking not only, but in form, which occur in the process of fissiparous generation are little known as yet, but there is a growing opinion that they are often great. I believe that in all the *Coscinodisceæ*, at least, variations in this respect occur as the new broods of diatoms grow smaller, until the departure from the type has been considerable; but when conjugation again takes place, two (perhaps) deformed irregularly marked specimens will produce a symmetric, fair, and typical form again. In plate 5, fig. 9, is a photograph of a small example which might well be exhibited as specifically different from the types we have been considering, but it is my opinion that its variation has been the result of the process just spoken of.

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*Jour. of Mic. Science, vol. 8, p. 94. (1860.)

† Am. Jour. of Mic., vol. 2, p. 100.

‡ As it has been impracticable for the Society to present photogravure plates of more than a few of my photographs, the engravings will be referred to by number of plate and figure; the others simply as photos No. 1, &c.

E. Considerable changes of form may occur without becoming the ground of new species.

This, which is closely connected with the last subject, may be passed with brief treatment, as the statement is generally accepted. Some extension of its application has been hinted at in my paper on Deformed Diatoms (*ante*, p. 182), and I will only add a suggestion of the manner in which such forms as *Palmeria hardmaniana, Grev.* or *Euodia gibba, Breb.* (= *Hemidiscus cuneiformis, Wallich* *) may temporarily arise. If, from any mechanical or other obstruction in its growth, one of the fasciculate forms of the *Coscinodisci* should have its two valves become adherent on one side during its early and unsilicified state, the hardening of the tissue by the silex would force its growth into the *Euodia* form, so closely resembling a bivalve; but in the process of further fissiparous division the character of this mode of reproduction forbids and prevents the return to the type by reason of the inflexible character of the box in which the self-division takes place. Consequently we can have no return to the type till conjugation takes place, and an indefinite number of generations of this deformed character may succeed each other meanwhile. Under such circumstances, it would seem to me inadmissible to call the new form anything but a temporary variation till the frustule formed after conjugation shall be shown to keep its peculiarities. Even then, if side by side with it the typical form is found, it can hardly be said to be more than a permanent variety. Yet, on what seems to be such a distinction, we see, in the example given, two new genera founded.

F. Sparseness of alveoli is often misleading as to pattern of marking and is not reliable as a specific distinction.

The misleading effect of sparseness is analogous to that already mentioned in the case of fascicles reduced to a minimum number of lines. The scheme is less visible, though easily traced when the clue is given. In photo. No. 6 is an example of *Actinocyclus* from a recent gathering at the Samoa Islands, Pacific Ocean, in which the scheme of marking is that of three-lined fascicles, but the sparseness of the dots makes it difficult to trace the pattern. In some of the smaller specimens of other fasciculate forms the difficulty is even greater, and I believe that these are often regarded as lacking a definite pattern when larger specimens (less removed from the conjugate frustule) would show it clearly.

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* Supplementary Series of Photo's, No. 5, from Moron (Spain) deposit.

An analogous difficulty is found when the marking is hexagonal and made up of large alveoli. In such cases the scheme or pattern, as shown by the inner plate or lamina of the valve, is that of sparse dots, but the hexagons above are not strictly symmetrical or even. There is, consequently, a great difference in the apparent marking when we focus upon the outer surface (showing the hexagonal marking) or upon the inner surface, showing the pattern of the dots. Photographs Nos. 7 and 8 are taken in this way from a *Cos. radiolatus*, Ehr. (= *C. curvatulus*, Grun.), from the Santa Monica deposit.

G. A striated margin is often apparently present or absent, as more or less of the beveled marginal zone of the fasciculate forms is shown.

I have often found examples of *Actinocyclus* and of *Cos. subtilis* in which the beveled edge before mentioned was a little flatter than common. In these the appearance of a separate scheme of marking for the margin is illusory. It can hardly be contended that a little more or less bevel at the margin is a specific difference. If the hoop or connecting zone of the frustule is uncommonly stout, the valve will often show a circular line within the extreme circumference and parallel to it, where the attachment of the hoop has left its trace. In such cases the real difference is in the stoutness of the hoop, which is as variable a quantity as the other. Photo. No. 9 is from an *Actinocyclus* from the Santa Monica deposit, showing this apparently strong and striated margin. No. 10 is another from same kind, a little less regular in pattern, apparently in consequence of a wave or roll in the surface of the shell showing more plainly. Nos. 11 and 12 are prints taken at different focus from another specimen of the same group, showing the subhexagonal marking on the surface and the general scheme at a deeper focus.

H. New species have often been based upon different valves of the same frustule.

Every student of diatoms knows that in some species the valves are dissimilar; *e. g.*, in *Cocconeis*, *Achnanthes*, &c. I have found frustules of *Cos. subtilis* whose valves varied in the number of fascicles, and I have found others in which one valve was *C. symmetricus*, and the other the irregularly fascicled form which some systematists consider the true *C. subtilis*. These specimens occurred in recent gatherings from the coast of Florida (Jacksonville), and from Hudson river (Poughkeepsie). That they occasionally pass from one form to the other is conclusive proof that the difference is neither specific, nor that of permanent variety. Photo's Nos. 13 and 14 are of specimens from the Poughkeepsie water supply and very well illustrate the variation, though these are not valves of the same frustule. From general size, appearance, and association in the same gatherings, such relations may be fairly surmised, and experience often justifies the suspicion. The rejection of the number of fascicles, &c., as a specific distinction was first based on this general suspicion. Prof. H. L. Smith has expressed his suspicion that *Cos. concinnus* (*Eupodiscus Jonesianus*, *Grev.*) and *Cos. nobilis*, *Grun.* are differing valves of one frustule,* and the opinion of so experienced and sagacious an observer may safely be accepted, provisionally, at least.

I am quite satisfied in my own mind that the so-called *Coscinodiscus excentricus*, *Ehr.*, is only a form of *Cos. lineatus*, and often a valve of a frustule of which the other half is the latter type. The cumulative character of the reasoning is something on this wise: The essential character of the marking is the same. They are found constantly associated and often so identical in all the subordinate characters of size, robustness, color, &c., as to have the same relations to each other in these respects that specimens of any common pure gathering have. The difference is one easily accounted for by what we know of diatom structure and growth *without* assuming difference of species. The peculiar honeycomb marking of *C. lineatus* is dependent on flatness of surface, and its regularity will be disturbed if the surface is convex. In this case a wedge-shaped segment or gore must be taken out to allow the surface to curve, and the bringing of the edges of the gore together will disturb the parallelism of the marking exactly as we find it in *C. excentricus*. It thus appears that the difference is not one of scheme of marking, but of the application of the pattern to a flat or convex surface. This in itself ought to settle the question of *specific* difference, for nobody has pretended to make slight variations of curvature of surface a basis of species. But this is not all. The very closely allied *Stephanopyxis corona, Ehr.*, is known to have its two valves of different curvature, the circlets of spines being further from the margin in the more convex valves, as they must be to fulfill their office of holding the frustules together in the earlier phase of their life history.* In the fair, large specimens, which figure in Möller's Typeplate as *Systephania corona* and *S. diadema*, we have in the flat valves the regular *C. lineatus* with the marginal circlet of spines strong and sometimes confluent. I have again and again found these in frustules of one valve of each so-called species in the Richmond deposit. Photo. No. 15 shows a typical *Cos. lineatus* from the Nankoori deposit. Nos. 16 and 17 are from *Systephania*, in the Richmond deposit. I cannot think them either generically or specifically distinct. The spines will be mentioned in next paragraph. I regard *C. excentricus* as identical with *C. lineatus*, and *Systephania* as, at most, a variety of the same, the tendency of the valves of a frustule to vary in convexity being characteristic of the whole group.

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* Am. Jour. of Mic., vol. ii, p. 103

In plate 4, fig. 4, published herewith, is an exceptional specimen of *C. excentricus*, which looks at first sight very like *C. subtilis*, the surface being divided into seven fascicles or compartments. Closer attention, however, will show that the arrangement of the hexagons is that of the *C. lineatus* group and not the other. The gore lines in the so-called *excentricus* may be one or several, but they rarely come so near to a *symmetrical* irregularity as in this example.

I. Marginal or intra-marginal circlets of spines are a very variable character.

I have spoken in the early part of this paper of the normal form of the species under consideration, and do not doubt that in perfect types the small spines are marginally placed, as I have indicated. Their office is the strengthening of the hold of the frustules upon each other in the movements and strains to which these are subject before becoming "free;" but the spines vary greatly in prominence, in number, and in regularity of spacing. They have very often been overlooked because very small. I have very rarely failed to find them on the margin of the fasciculate species. Even when they cannot be seen in focus, if the microscope tube is raised a little they will be detected by the *coma* or shadow exaggerated in this way. Plate 5, fig. 7, is an example of the way in which this appears, in a case where the spines were nearly or quite invisible when in sharp focus. The genus *Odontodiscus* which Ehrenberg based on these spines was rightly cancelled by H. L. Smith. They are not always present in the fasciculate species, though rarely absent. They are often found in *Cos. radiatus* of the most robust varieties, as *C. oculus iridis*, &c. They are not always symmetrically placed in the fasciculate species, though they usually are. Sometimes there will be a spine at the margin of only the alternate fascicles. I have notes of some instances in which they were numerous around one quarter, say, of the circumference of a *C. subtilis*, and absent elsewhere. Such are exceptional cases.

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* Van Heurck's Atlas, pl. lxxxiii, *ter.*, fig. 11.

The more numerous the spines are, the more irregular they are apt to be. This is very marked in *C. lineatus*, in which the circlet is apt to be interrupted. In robust growth the circlet is often fimbriate or confluent. These variations are so evident in undoubted examples of a given species (or even variety) that it is impossible to base specific distinctions upon them. The photographs above referred to illustrate this. An additional reason is thus found for relegating *Systephania* to *Cos. lineatus*. The tendency to a central (or interior) circle of spines in *C. lineatus* is shown in the fact that one or two small spines are very often found near the center of the valve without others, and this in specimens from very widely separated *habitat*.

What I have thus said of spines is of much more wide application than to the *Coscinodisci*. On *Triceratium favus*, *T. spinosum*, &c., they are very variable. On *Eupodiscus radiatus* from the Florida coast I have often found complete *alæ* surrounding the valve, and in their nature a confluent growth of spines.

K. The rosette in the center of *Cos. radiatus*, &c., is not a mark of species.

This follows from the structure of the rosette, when we ask what causes it. The alveoli are the quasi-pores through which endosmose takes place to support the life and growth of the plant. They resemble a bubble between the siliceous laminæ of the valve, the surrounding solid parts being of the full thickness of the bubble. When the alveoli crowd upon each other the solid walls (in this genus) become hexagonal in the areolation. When either the shell is very thin or the alveoli are comparatively sparse, a central space of clear silex is left, such as Ehrenberg made the mark of the species *Cos. perforatus*. Photo. No. 18 is taken from a specimen in the Holland's Cliff (Maryland) deposit, in which all the alveoli are round dots, and the radiation illustrates the description I have given of *Cos. centralis* as a type. From this small form, photographed, the series runs through *Cos. centralis* to *Cos. gigas.* In the intermediate stages are numerous examples, in all our Maryland and Virginia deposits, of valves areolate partly in dots and partly in hexagons, one limb of the disc being usually (in such cases) different from the other. Such irregular forms have been classed as new species under name of *Cos. obscurus, Schmidt,* &c. As the robustness of the shell increases and the alveoli become hexagonal, the laminæ are of course separated by these cellule-walls. Each inner alveolus spreads more or less into the central blank space, making a shallower extension of the hollow in that direction. In very robust and thick shells of *Cos. radiatus* (*e. g.*, those known as *C. oculus iridis, C. omphalanthus,* and *C. asteromphalus*) the separation of the laminæ and the extension of the inner circlet of alveoli have gone so far that little or no blank space is left, the rosette leaves meeting in the center of the shell.

It is well known that the under lamina of the shell is not areolated into hexagons like the upper, but the "eye-spot" (a circular thin spot in the silicated membrane) is seen at the bottom of each alveolus as we focus down to it. In the rosette or "anthus" these eye-spots are found in the outer part of the elongated alveoli, approaching no nearer to the center in *C. radiatus* than in *C. perforatus.* The appearance of the rosette is, therefore, the index of the thickness and robustness of the shell, and in itself has no other significance. Plate 4, figs. 2 and 3, are photographs of the rosette of *C. oculus iridis, Ehr.*, from the Nottingham, Maryland, deposit; in the first the focus was upon the dotted upper surface, and in the second upon the eye-spots beneath in the same shell. My note books of 1885 are full of notes and measurements of these rosettes, in which overwhelming evidence was collected of the passage of the small round alveoli into hexagons and these into the "anthus," the "eye-spots" approaching no nearer the center of the shell.

The series of forms which I class under *Cos. centralis* have, however (besides their peculiarity of radiation), a tendency to thinness of the central part of the shell in the largest valves, which are presumably nearest in generation to the conjugate frustule. *Cos. radiatus*, on the other hand, grows stoutest in the largest specimens. It is easy to make a series beginning with *Cos. perforatus* in round dots, passing by almost infinitesimal degrees through forms partially or wholly in hexagons to *Cos. centralis,* with shallow "anthus" or rosette, and with alveoli increasing in size outward, and from this to *Cos. gigas* of the Richmond earth, in which the rosette has disappeared, the central alveoli diminishing to mere points in the delicately thin shell, but increasing gradually outward to the few rows of very large and deep alveoli which are found at the margin. This tendency to thinness of center in this species is best seen in a field where they are numerous and viewed with a low power. Photographs Nos. 19 and 20 of my supplementary series show this clearly. They are from slides of the Richmond earth, which is very rich in *Cos. gigas* and its congeners.

The rosette will be found whenever the shell is robust in comparison with the size and number of the alveoli. It is found in *Cos. Concinnus* and other forms of fine areolation, as well as in the great specimens I have named. I am thus justified in concluding that the rosette has no *specific* significance, since we find it appearing, disappearing, and changing form in the same species with the robustness of the specimen and the amount of silication.

Before passing to the next topic I invite attention to the analogy between the numerous examples of *Coscinodiscus* with one limb or segment in dots, whilst the rest is in hexagons, and the supposed case by which I have accounted for the *Euodia* and *Hemidiscus* forms. In the former we have examples of valves manifestly thinner in one portion than elsewhere. Increase this difference and the conditions will be present for the adhesion which I have supposed to be the occasion of the lunate forms.

L. *Craspedodiscus* is not generically or specifically distinct from *Coscinodiscus.*

The typical forms are *Cras. elegans*, Ehr., and *Cras. coscinodiscus*, Ehr. The former is found associated with the large *Cos. radiatus* (*C. oc. iridis*) of the Virginia and Maryland earths. The latter is more widely distributed. The remarkable size and general structure of *Cras elegans* and its general agreement in all qualities of structure and form, except the roll near the rim, would naturally suggest its close relationship to the gigantic *Coscinodiscus*, in whose company it is found. The suggestion gains weight when we find that large specimens of *Coscinodiscus* from all parts of the globe show a tendency to a similar wave or roll. Sometimes nearly the whole disc will be thin and flat, but two or three rows of alveoli around the rim will be more robust and show a pronounced upward curve. Numerous examples of this sort are found in Möller's slides from Saldanha Bay guano. It is in examining the Richmond earth itself, however, that the evidence grows conclusive. In a gathering made by Mr. Peticolas, in Buchanan street, in Richmond (1881), the *Cos. oc. iridis* is found with the roll or wave in every degree of progress. In these it is often on only one-half the shell or less, the other half having the normal marking of *Coscinodiscus*, and even in the roll the form of the alveoli is little, if any, distorted. An example of this is shown in a broken shell, Photo. No. 21. The roll is rarely perfect all around the shell. There will nearly always be found a place where the wave slides gradually into the disc, as may be seen in Schmidt's figure (Atlas, pl. lxvi, fig. 1). When the roll is boldly formed the alveoli are lengthened radially to suit the increased distance, being thus distorted from the normal hexagons into lozenge shape.

In the smaller forms of *Craspedodiscus* it is usually the thin depressed center in which the alveoli are distorted or aborted. Here the process is evidently similar to that which I have several times mentioned. The upper and under films of the valve are not fully differentiated, and the alveoli are partly degraded or suppressed. I look upon it as one of the forms which result from the crumpling or crowding of the shell in its early stage of growth, when the daughter cells are too vigorous for the silicified matrix in which they are formed. The weak part of the valve will give way in such cases. Schmidt's plate lxvi is a valuable study, showing how this force acts in different species of *Coscinodiscus*. I believe that the same cause produces *Porodiscus* and the roll in *Actinocyclus* which must also be denied the importance of a specific distinction. *Cos. excavatus*, Grev. (Sch. Atlas, pl. lxv, fig. 1), is, in my opinion, only another development from a similar cause, and the whimsicality of our diatom nomenclature is strikingly shown in the fact that the latter has been retained in the genus *Coscinodiscus* whilst the others have been ranked as independent genera. If one roll or depression makes a genus, *Cos. excavatus* should have that honor, "*ter quaterque*" *!* Photo's Nos. 22 and 23 illustrate different stages in the smaller *Craspedodiscus.*

M. The occurrence of two thin places in the rim of *Coscinodiscus* is not a mark of species.

This character is figured in Schmidt's Atlas, pl. lxiii, fig. 13, and on it *Cos. biangulatus*, A. S., is founded. In my studies of *Cos. radiatus* I have found that whenever this species reached a certain robustness the two thin places (a little more than 90° apart) may always be detected in the rim. Since 1885 my note books overrun with evidence of it. I traced it in the so-called *Cos. oculus iridis* of the Jutland cementstein, in *Cos. radiatus* of the North Sea (Cuxhaven) gatherings, in all the Virginia and Maryland deposits. Photo. 24 shows this appearance when the rim is focused upon, and No. 25 when the surface of the valve is in focus. These specimens are what I regard as the large form of *C. marginatus*, *Ehr.*, where it is hardly distinguishable from *C. radiatus*, except by the continued thickness of the rim. Plate 4, fig. 5, is an example from Beach Haven, N. J., the northern extension of the Maryland fossil deposits. In it the progress toward a triangular form is shown in further development. This is very interesting as indicating an explanation of the manner in which this disc form becomes triangular. In the Petersburg, Va., earth I have found a perfect triangle, but of much finer marking, in which two of the corners were marked by the common blank spot, but the third lacked it, the marking being there continuous over the angle. It is significant also that in *Cos. concinnus* the prominent processes are placed as these undeveloped processes are in *C. radiatus.* I look upon this character, therefore, as probably present in all varieties of *C. radiatus*, becoming noticeable when the forms are robust. It becomes, consequently, a natural mark by which to connect and diminish species, not to enlarge the list.

N. Confluence of alveoli into larger ones is not a mark of generic difference.

This has been generally accepted in the *Navicula* tribe when the original distinction in genus of *Pinnularia* from *Navicula* has been cancelled. The reason for it was not that which may now be given, for the true nature of the alveolus was not at first recognized. Now we know that what we call the costate form of *Pinnularia* simply means that the rows of alveoli have become confluent into one, the elongated "eye-spot" being found in the inner film smaller than the outer film of the alveolus, but keeping the relation of parts and of office which exists in the circular or hexagonal alveolus. The same is seen, in a less degree, in the long alveoli of many of the didymous forms of *Navicula.*

I suspect that something similar has occurred in the so-called craticular plates of *Naviculæ* (*e. g.*, *Surirella craticula*, &c.), though these have not yet been proven to have double films in the thin parts which make the sculpture of the figure. Although a little beyond my present subject, I will refer to some examples of craticular plates found by our late lamented member, Dr. Sloan, and his coworker, Dr. Clapp, of New Albany, Ind. These accurate observers found in considerable numbers compound frustules of *Navicula cuspidata*, in which there was this regular series: The two exterior valves were typical *N. cuspidata*, with produced ends and fine transverse striæ. Within these was a frustule, of which both valves had the strong radiant marking of *N. radiosa.* Innermost of all was the single craticular plate (*Sur. craticula*). They found these so frequent in a gathering of diatoms near their home that they mounted some slides in their unexcelled method, and I had the pleasure of verifying their description. Passing by the bearing of this on the problem of variation of species, I call attention to the fact that, so far as I know, the craticular plate is always single, never a frustule. If we suppose that fission had begun, but the new frustule aborted, and the two valves unite in one silicified plate in which the alveoli never develop, but thin places roughly simulate the normal pattern, we may get at least an intelligible idea of the way in which such a plate may be formed consistently with the common laws of diatom growth and structure.

Plate 5, fig. 8, shows a plate found in the Barbadoes deposit which agrees pretty well with the characters of *Actinogonium* (see Van Heurck's Atlas, pl. cxxvii, fig. 8). In this instance the marking is that of a small but coarse *Cos. radiolatus* (= *C. curvatulus*), in which the dots had become confluent in shallow, thin canaliculi or grooves. The radial lines have on one side of them shorter lines, diminishing in length, following the pattern of the *Coscinodiscus* in examples, which have fascicles of few and stout lines of dots. Van Heurck doubts the claim of his figure to be a new genus, thinking it a craticular plate of *Asterolampra.* It seems to me more closely connected with *Coscinodiscus.*

But in plate 4, fig. 1, I give the reproduction of a photograph from a shell found in the Petersburg, Va., deposit, which seems to me to throw fresh light on the subject. The figure is that of *Coscinodiscus subtilis* with six symmetrical fascicles of numerous lines, in which the alveoli seem to have become confluent, with a few exceptions, which remain, as it were, for proof of the normal pattern from which it is a variation, and of which it is a diagram prepared by nature. It seems to me very similar in character to the last object described, though more elaborate. Its peculiarities would, no doubt, seem to many worthy of a new generic name; but I do not at all believe it is anything else than an exceptional form of *Cos. subtilis.* In Truard & Witt's diatoms from Jeremie, in Hayti (T. & W., pl. 5), are examples of a similar confluence of alveoli in triangular forms, which are very interesting for comparison with this.

I had intended to add a few lines upon the valueless character (for purposes of specific distinction) of apiculi near the center of the fasciculate forms, as in *Cos. stellaris, Roper*; *Symbolophora trinitatis, Grun.* (not *Ehr.*) of the Möller Type Plate, &c., and also of the irregular variability in number and spacing of the central alveoli in *Actinocyclus* and the other fasciculate *Coscinodisci:* but I have filled as much space as seems proper for a single paper.

My general purpose has been to show that with all the wonderful simulation of geometric forms in diatoms they still, like other vegetables, have a large variability and a free application of the normal patterns to changing conditions of growth; next, to point out the numerous directions in which our increasing knowledge of the anatomy and physiology of these plants shows that supposed specific differences are accounted for as merely individual peculiarities of growth or condition, or, at most, as temporary varieties; lastly, to emphasize the fact that the enormous multiplication of species destroys the scientific value of classification and bars the way to a rational system. Instead of waiting for fuller knowledge, observers have run headlong races to publish new genera and species upon a single specimen or even fragment of a specimen. Much of the later so-called systematizing has been only an "*enumeratio simplex*" of individuals, from which, as Stuart Mill in our youth taught us, there is no logical induction.

It seems to me a duty to say that it is practically impossible to identify species with any certainty among the diatoms with the published means now at command. Artificial keys have become complicated and delusive. The searcher with a specimen before him soon runs upon vague and ambiguous distinctions, and is fortunate if he does not find a dozen described species to either of which it may with equal plausibility be attributed. Life is too short and human memory too finite for any one mind to master the catalogues of species which multiply by fission as rapidly as do the diatoms themselves under favoring conditions. I venture to say that no living student in this department can be sure that he has a new species (much less a new variety) before him. The impossibility of being certain leads an observer to solve his doubts in favor of his own discovery, and the same object is named and renamed.

To illustrate this, let me refer to my reasons for making *Cos.*

radiolatus, *Ehr.*, rather than *Cos. curvatulus*, *Grun.*, the third, and *Cos. marginatus*, *Ehr.*, the seventh of the typical forms treated in this paper. The early observers did not fully resolve the markings of their specimens, and therefore often missed a full description. This does not absolve us from the duty of determining what they had under their microscopes. Not to do so is to leave scientific lumber behind us to block the way of all future investigators. To solve the doubt in favor of any probable and definite form to which figure and description will reasonably apply is better than to ignore them and add a new name of species to the list. The deposits and gatherings examined by the early microscopists can generally be duplicated, and no work is more profitable than earnest effort to follow their steps with our better instruments, sympathetically and not too critically. Treated in this way, Ehrenberg's work, as reported in *Berl. Bericht*, and Prof. Bailey's in Silliman's Journal, throw mutual light on each other. The history of *Cos. subtilis* and *Cos. radiolatus* show that these species were regarded as closely allied, though the fascicles of neither were accurately described. Bailey identifies them as found in the Bermuda (Nottingham), the Richmond, and the Petersburg deposits. Following this clue and carefully noting the original criteria of other *Coscinodisci* in the same deposits, I have satisfied myself that the two types, *subtilis* and *radiolatus*, are those which were distinguished in fascicles as I have described them. Some years ago I named as *Cos. subtilis* var. *molaris* (mill-stone) the *radiolatus* form with straight lines in the fascicles, and deposited photographs with this Society and the R. M. S. of London, accompanying a paper on Broken Diatoms. This name should be cancelled as well as *C. curvatulus*, Grun., unless I am wrong in attributing it to Ehrenberg. Ehrenberg noted several forms under names of *Cos. marginatus*, *Cos. concavus*, *Endictya oceanica*, &c. (found also by him in our American deposits), which, for reasons already hinted at, I believe to be forms of one species in different stages of the life-history of a diatom-lineage. If I am right, the type is the form which results immediately from conjugation, and is the larger, flatter, most regular in marking, and with least recurved rim. This is *C. marginatus*, Ehr., and I do not think it specifically distinct from *C. robustus*, Grev., and some others under different names.

The seven typical forms to which I have confined my attention in this paper represent several hundred species as given in the catalogues. The criteria on which the long list is built (ignoring numerous mere multiplications of names) are nearly all those which I have discussed. I earnestly believe that the whole should be reduced to these with comparatively few varieties of each. I must not be understood as including all *Coscinodisci* and *Actinocycli* in this assertion; but the several hundred which have the typical marks I have attributed to these seven. This gives my measure of the reduction which, I think, would result from a thorough and scientific revision of the whole family.

Whoever will turn to Dr. William Gregory's paper on "Shape or Outline as a Specific Character in the Diatomaceæ," in the Transactions of the Royal Microscopical Society for 1857 (Q. M. J., vol. iii, p. 10, *Tr.*), will find an argument with a telling object-lesson on the useless multiplication of species, even at that day. It is in the effort to imitate the spirit of that eminent naturalist that I have prepared these remarks. Lest I should be misunderstood, I will add, in closing, that the abundant material presented, with admirable figures from reproduced photographs, in such works as Schmidt's Atlas, Truard & Witt's Jeremie Diatoms, and Pantocsek's Hungarian Diatoms are invaluable and trustworthy material for our study. If we shall only establish true criteria of species based on wider familiarity with the life-history of each, we may hope ere long to remove the reproach that our department of investigation is being literally gorged with undigested material.